

Fig. 2. Experimental setup.

### 3. Experimental results

#### 3.1. Experimental setup

The laboratory prototype consist of a servomotor from Moog, model C34-L80-W40 (Fig. 2) driven by a Copley Controls power servoamplifier, model 423, configured in current mode. A BEI optical encoder, model L15 with 2500 pulses per revolution, allows measuring the servomotor position. The algorithms are coded using the MacLab/Simulink software platform under the program Wincon from Quanser Consulting, and a Quanser Consulting Q8 board performs data acquisition. The data card electronics increases four times the optical encoder resolution up to  $2500 \times 4 = 10\,000$  pulses per revolution. The control signal produced by the Q8 board passes through a galvanic isolation box. The software runs on a personal computer using an Intel Core 2 quad processor, and the Q8 board is allocated in a PCI slot inside this computer. The following transfer function, which is composed of a high-pass filter in cascade with a low-pass filter, allows obtaining velocity estimates from position measurements.

$$G(s) = \frac{400s}{s + 400} \frac{500}{s + 500}$$

The low pass filter attenuates the high frequency components of the position signal. The Simulink diagrams use a sampling period of 0.1 ms and the ODE5 solver. Fig. 2 depicts the experimental setup.

#### 3.2. Experiments

##### 3.2.1. Parameter identification

Two Duffing systems generate the signal used for exciting the servomechanism

$$\ddot{x}_1 = x_{21}\omega_1\pi \quad (31)$$

$$\ddot{x}_2 = [-0.25 + x_{21} + x_{11} - 1.05x_{11}^2 + 0.3 \sin(\omega_2\pi t)]\omega_2\pi; \quad i = 1, 2$$

$$x_i = 7x_{11} - 5x_{22}; \quad x_{11}(0) = 0; \quad x_{21}(0) = 0;$$

$$\omega_1 = 1 \text{ rad/s}; \omega_2 = 2 \text{ rad/s}.$$

This type of chaotic excitation was proposed in [24] for parameter identification of a speed controlled servomotor. Fig. 3 shows the time evolution of  $x_{11}$ . The gains for the PD controller are  $k_p = 10$  and  $k_v = 0.28$ , and the update law gains are  $\Gamma = \text{diag}\{12 \ 3000 \ 180 \ 90\}$ .

Fig. 4 shows the time evolution of the parameter estimates obtained using the proposed approach. Fig. 5 depicts the input error  $e_u$  and the evaluation of the PE condition (30) with  $v = \frac{1}{2} [1 \ 1 \ 1 \ 1]^T$ ; the values for the PE condition in Fig. 5(b) are

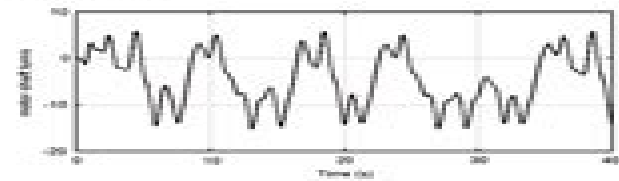
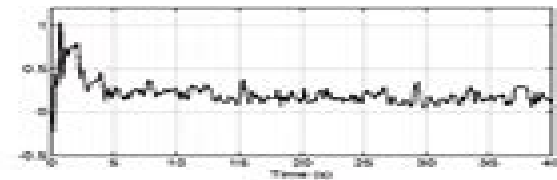
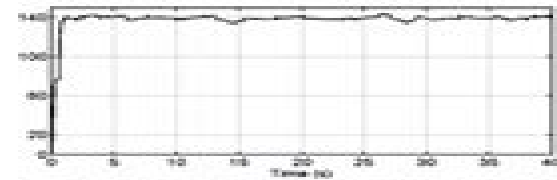
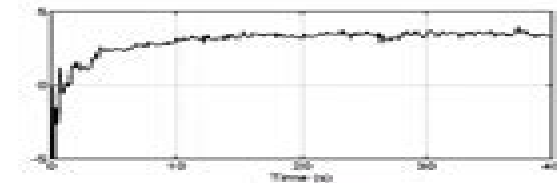
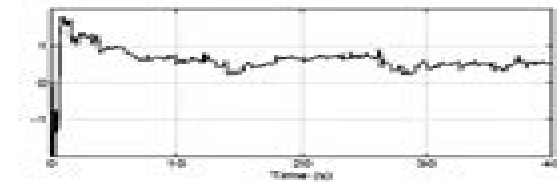


Fig. 3. Chaotic excitation signal.

Parameter estimate  $\hat{a}$ Parameter estimate  $\hat{b}$ Parameter estimate  $\hat{c}$ Parameter estimate  $\hat{d}$ Fig. 4. Parameter estimates obtained using the CLIE method:  $\hat{a}$ ,  $\hat{b}$ ,  $\hat{c}$ , and  $\hat{d}$ .

shown every five seconds, i.e.  $\delta = 5$  s. Hence, the regressor vector fulfills the PE condition during the experiment. Table 1 shows the parameter estimates obtained from the experiment. They were

# Servomechanism Analysis

**Jessica J Manson**



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*Servomechanism Analysis* George Julius Thaler, Robert George Brown, 1953      *The Analysis and Synthesis of Linear Servomechanisms* Albert Carruthers Hall, 1947      Servomechanisms United States. Army Materiel Command, 1965

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*The Study of a Relay Servomechanism* Silas Earl Carmean, 1961      *Linear Operator Analysis of Carrier-frequency Servomechanisms* Charles August Halijak, 1956      **Servomechanism Fundamentals** Henri Lauer, Robert Lesnick, Leslie E. Matson, 1947      A Survey of Stability Analysis Techniques for Automatically Controlled Aircraft Arthur L. Jones, Benjamin R. Briggs, 1951 A survey of the stability analysis techniques for automatically controlled aircraft is presented The survey is limited to techniques commonly applied to linear continuous control systems wherein the difference between the output and input quantities is measured continuously and is used in the operation of the system a closed loop system An evaluation of the techniques based on the kind and amount of information derivable is included An illustrative example is also presented to demonstrate the calculations involved for a typical aircraft autopilot combination      **WADC Technical Report** United States. Wright Air Development Division, 1954      *A Differential Analyzer Study of Certain Nonlinearly Damped Servomechanisms for Various Input Signals* Ralph Russell Caldwell, 1952      Handbook of Supersonic Aerodynamics R. J. Volluz, 1961      Research in Nonlinear Mechanics as Applied to Servomechanisms Cook Electric Company. Cook Research Laboratories, 1954      **Handbook of Supersonic Aerodynamics** Johns Hopkins University. Applied Physics Laboratory, 1961      Ordnance Engineering Design Handbook United States. Army. Ordnance Corps, 1959      Technical Abstract Bulletin , 1964      **Applied Mechanics Reviews** , 1974      **AFPTRC-TN.** , 1956      *Annual Catalog - United States Air Force Academy* United States Air Force Academy, 1962      United States Air Force Academy United States Air Force Academy, 1963      **Current Hydraulic Laboratory Research in the United States** , 1964

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